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# METHOD AND DEVICE FOR PRODUCING PRECISION INVESTMENT-CAST NE METAL ALLOY MEMBERS AND NE METAL ALLOYS FOR CARRYING OUT SAID METHOD

**[0001]** Precision casting production of nonferrous metal alloys, preferably of TiAl components, in particular for use in the turbine engineering sector, is expensive and difficult, since alloying elements evaporate out of the melt during the heating and casting operation, interfacial layers which have an adverse effect on the casting operation are formed, and there is a risk of casting voids being formed, leading to destabilization of the alloying microstructure. In this context, it should also be taken into account that the time required for the actual casting operation is negligible compared to the time required to heat up the melt.

**[0002]** Components of this type produced by precision casting are therefore subsequently to be treated by means of what is known as an HIP process, i.e. casting voids need to be compacted by a hot isostatic pressing operation, and the microstructure of the component produced by casting needs to be stabilized by subsequent heat treatment.

**[0003]** Therefore, it is extremely expensive to comply with predetermined materials specifications for components to be produced in this manner, and high scrap rates are inevitable.

**[0004]** This is where the invention intervenes; the object of the invention is to significantly improve the production of components from nonferrous metal alloys in particular for use in the turbine engineering sector by means of precision casting.

**[0005]** Proceeding from the known centrifugal casting process, in which the centrifugal forces influence the shaping, mold filling and crystallization of the melt as a result of rotation of part of the casting device, this object is achieved, according to the invention, by a process for dimensionally accurate precision casting production using casting molds which correspond to the external shape of the components to be produced in each case, comprise heated mold shells and to which the melt is supplied via a heated runner device, in such a manner that the casting molds are completely filled by means of the acceleration forces and the Coriolis forces occurring during rotation, and the centrifugal forces applied to the melt.

**[0006]** According to a further feature of the invention, the melt for the casting operation is diverted through approximately 30° - 180° by means of the centrifugal forces counter to the direction of flow determined by the force of gravity, and as it flows into the casting molds is forced to homogeneously fill the casting molds by the Coriolis forces.

**[0007]** According to a further feature of the invention, the heated runner device and the heated casting molds are held at predetermined process temperatures which correspond to the nonferrous metal alloys used for the precision casting production, maintain the ability of these alloys to flow and are preferably 10 to 200°C above the melting point of the nonferrous metal alloy.

**[0008]** The process according to the invention includes a number of advantages.

**[0009]** Surprisingly, it has been found that the process according to the invention lowers the evaporation rate of the melt, and the fact that the runner device has been optimized in terms of fluid dynamics, in order to utilize the Coriolis forces, means that the porosity of the castings is reduced in terms of the decrease in the size of the pores which can be achieved in the melt, and consequently it is possible to achieve finer microstructures than hitherto. Therefore, there is no longer any need for any further treatment of the demolded castings by hot isostatic pressing and subsequent application of heat to stabilize the microstructure of the alloy. This leads to a significant reduction in costs during production of components of this type and to savings in terms of the materials costs for the nonferrous metal alloys to be used in terms of quantity, composition and purity. Furthermore, the scrap rate is reduced and further treatment costs are greatly lowered if not eliminated altogether.

**[0010]** To carry out the process according to the invention, the invention uses, as the runner device, a vertically positioned, rotatably mounted, cup-like vessel with a base surface which is designed to be favorable in terms of fluid dynamics, with which vessel the casting molds, which are assigned to its lateral surface, are arranged at a predetermined distance from the base surface and comprise mold shells, are in communication, the three-dimensional setting angle of which

casting molds with respect to the respectively associated outlet openings, which are likewise designed to be favorable in terms of fluid dynamics, of the vessel is adjustable, all this being arranged in such a manner that the casting molds are filled without any flow detachment in the melt.

**[0011]** According to a preferred exemplary embodiment of the invention, vessel and casting molds consist of ceramic which is relatively unreactive with respect to the melt and has included metal particles, so that vessel and casting molds can be heated in an accurately controllable way, preferably inductively using inductors which are known per se or by means of microwaves.

**[0012]** It is advantageous if, according to a further feature of the invention, the runner channel, which is used to supply the melt, is likewise designed to be favorable in terms of fluid dynamics of the melt and consists of heatable ceramic which is relatively unreactive with respect to the melt and has included metal particles. However, according to a further exemplary embodiment of the invention, the melt may also be produced inside the vessel of the runner device while it is rotating.

**[0013]** Finally, filling devices and runner channel may consist of coated steel, coated graphite, tantalum, titanium or niobium.

**[0014]** According to the invention, the nonferrous metal alloy used is a TiAl alloy comprising 30 to 33% by weight of Al, 4 to 6% by weight of Nb, 0.5 to 3% by weight of Mn and 0.1 to 0.5% by weight of B, remainder Ti.

**[0015]** In the context of the invention, a TiAl alloy of this type comprising 0.5 to 3% by weight of Mn has an oxygen content of from 0 to 2000 ppm, a carbon content of from 0 to 2000 ppm, preferably 800 to 1200 ppm, a nickel content of 100 to 2000 ppm and a nitrogen content of 0 to 2000 ppm. Of course, it is also possible to use other nonferrous metal alloys to carry out the dimensionally accurate precision casting production in accordance with the invention.

**[0016]** Further features of the invention will emerge from the subclaims.

**[0017]** The invention is described below on the basis of two exemplary embodiments that are diagrammatically depicted in the drawing, in which:

**[0018]** Fig. 1 shows a first exemplary embodiment of an apparatus for carrying out the process according to the invention, and

**[0019]** Fig. 2 shows a modified exemplary embodiment of the apparatus shown in Figure 1.

**[0020]** The apparatus illustrated in Figure 1 shows a runner device, which can rotate about an axis 10, is denoted overall by reference numeral 11 and to which the melt is supplied from a casting ladle 12 via a runner channel 14 which is designed to be favorable in terms of fluid dynamics.

**[0021]** The runner device 11 is positioned vertically and mounted rotatably - the drive device required for this purpose is not shown for the sake of clarity - and comprises a cup-like vessel 15 with a rotationally symmetrical side wall 16 and a base 18 which is formed integrally on the side wall and is optimized in terms of fluid dynamics. Outlet openings 19, which are optimized in terms of fluid dynamics and are in communication with casting molds 22 comprising half-shells 20, are distributed symmetrically over the periphery of the side wall 16, at a distance a from the base 18.

**[0022]** The casting molds are connected to the vessel 15 such that they can be adjusted through three-dimensional angles sr with respect to the associated outlet openings 19. The adjustment of the angles sr is effected as a function of the relative densities of the nonferrous metal alloy used, the casting temperature and the rotational speed n of the vessel, and also the respective relative density of the alloy, so that the overall supply is designed to be optimized in terms of fluid dynamics.

**[0023]** The vessel 15 and the associated casting molds 22 are arranged in their predetermined position by means of a holder 23 which consists of a suitable ceramic, serves as a matrix for

them and is clamped between a base plate 24 and a cover plate 26. The melt, which has been heated to casting temperature, which emerges from the casting ladle 12 and is passed on via the runner channel 14, can enter the vessel 15 via an opening 28. By heating devices 30 which can be controlled with suitable accuracy - such as for example inductors - both the runner device 11 and runner channel 14 and the casting molds 22 are inductively heated in such a manner that the melt remains at the casting temperature until casting is completed. These temperatures, which maintain the ability of the melt to flow, correspond to the nonferrous metal alloys used for the precision casting production. For this purpose, runner channels 14, vessel 15 and casting molds 22 consist of ceramic which is relatively unreactive with respect to the melt and has included metal particles. However, it is also possible for vessel and casting molds to consist of coated steel, tantalum, titanium or niobium.

**[0024]** The term Coriolis force is known to refer to the inertia force which, in addition to the guiding force and centrifugal force, acts on a body moving in a rotating system. The Coriolis force is perpendicular to the plane formed by the velocity vector and the axis of rotation.

**[0025]** The nonferrous metal alloy used is a TiAl alloy comprising 30 to 33% by weight of aluminum, 4 to 6% by weight of niobium, 0.5 to 3% by weight of manganese and 0.1 to 0.5% by weight of boron, remainder titanium. It is preferable to use a TiAl metal alloy with an oxygen content of 0 to 2000 ppm, a carbon content of 0 to 2000 ppm, preferably 800 to 1200 ppm, a nickel content of 100 to 2000 ppm and a nitrogen content of 0 to 2000 ppm.

**[0026]** For the casting operation, the nonferrous metal alloy in the casting ladle 12 is converted into the desired melt by heating in the customary way and - as described above - passes via the heated runner channel 14 into the rotating, likewise heated runner device 11, where it passes onto the base 18 of the vessel 15 under the force of gravity. On account of the rotation of the vessel, centrifugal forces, which effect a change in the direction of flow of the melt of approximately 30° to 180°, act on the melt, so that it rises against the inner wall of the side wall 16 until it reaches the height of the outlet openings 19. Since the three-dimensional setting angles sr of the casting molds 22 are selected in such a manner as to coincide with the direction of the Coriolis force vectors, the latter act on the melt in addition to the centrifugal forces, with the result that

the melt can not only enter the casting molds via the openings 19, but also fills up the cavities of the casting molds adjoining the openings 19 quickly and reliably, and also completely and homogeneously. After the melt has solidified, the casting molds are removed and the corresponding precision-cast component is discharged in the usual way.

**[0027]** In the exemplary embodiment of the runner device which is illustrated in Figure 2, is denoted overall by reference numeral 40 and in which the components corresponding to the runner device 11 are denoted by identical reference numerals, the casting molds 22, the angular position sr of which is adjustable and which are held in the holding means 23, are located at the upper edge of the vessel 15, which is now mounted rotatably in the runner device 11. In this region, the vessel 15 has a distributor 42 which acts as a nozzle for the melt. The outlet openings 19 leading to the interior of the casting mold 22 are - as in the exemplary embodiment shown in Figure 1 - likewise designed to be favorable in terms of the fluid dynamics of the melt.

**[0028]** The nonferrous metal alloy is in this case fed to the vessel 15 as an ingot which melts in the rotating vessel, and consequently there is no need for the casting ladle 12 and runner channel 14 of the exemplary embodiment shown in Figure 1. For the ingot to be introduced into the vessel 15, the latter has a cover 44 which can be opened for this purpose and to which the distributor 42 is secured. For this purpose, the cover plate 26 is removably connected to the runner device 40. Since the vessel 15, which is likewise inductively heatable, is mounted such that it can rotate on its own within the runner device 40, heat-resistant seals 45 are provided between the inlet openings of the stationary casting molds 22 and the outlet openings 19 of the rotating vessel 15. The way in which the runner device described above operates corresponds to the way in which the runner device described in conjunction with Figure 1 operates, except that the supply of the melt into the casting molds 22, and therefore the filling of the casting molds 22, is favorably influenced by the distributor 42, which has a nozzle action.

**[0029]** For both embodiments, i.e. that shown in Figure 1 and that shown in Figure 2, it is provided that the cast components, while they are still in the casting molds, can be heated to 600 to 700°C, which is likewise effected inductively by means of the existing heater devices 30. In this way, the cooling rate of the cast components is kept at a controlled low level, in order to

avoid cracks, fractures and the like in the components. Therefore, the cast components are only removed from the casting molds after the particular desired degree of cooling, which is to be selected as a function of the composition of the nonferrous metal alloy used in each case, has been reached.

**[0030]** The invention described above for the first time ensures that the Coriolis forces of the centrifugal forces imposed on the melt can likewise be made to act in a controlled way, being applied to the melt in a similar way to a pressure ram, thereby displacing the melt completely and homogeneously into the casting mold so as to completely fill the latter without any voids and without any possibility of harmful flow detachment in the melt and of a differentially solidifying interfacial layer being formed. The heating of the cast component in the casting mold keeps the cooling rate at a controlled low level, so that the internal stresses which occur in the components in the event of uncontrolled cooling, and resulting cracks, fractures and the like, are avoided.